Public

EUV lithography scanner for sub 9 nm resolution

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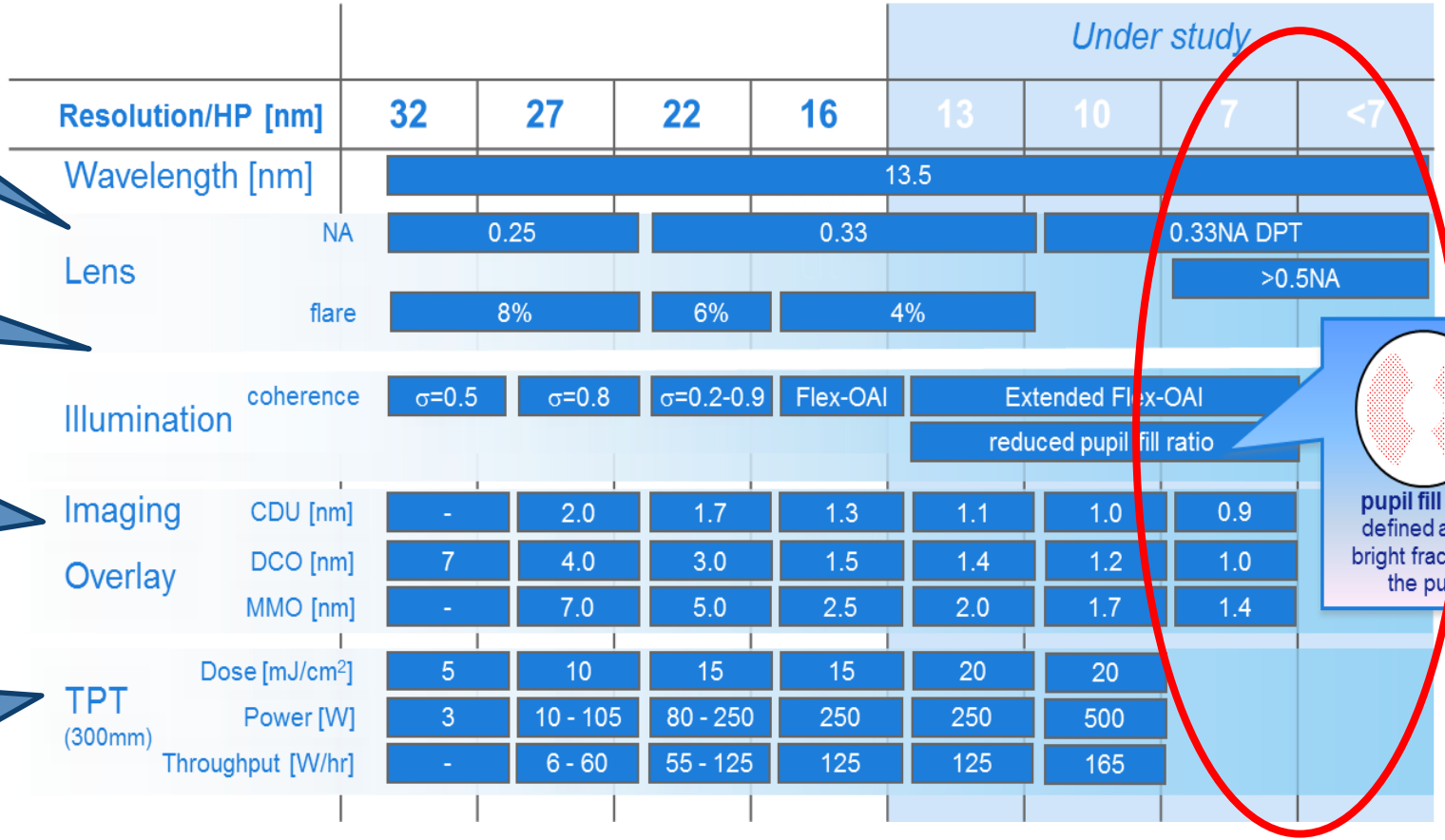
ASML EUV technology roadmap has extendibility through many nodes

Extend NA 0.33 to below 10nm

Improved lens and illuminator performance

Imaging / Overlay performance match node requirements

Increased throughput at higher dose



Summary

The Half Field anamorphic concept is a breakthrough for High NA EUVL:

We can now extend the EUV Technology roadmap below 9nm with NA > 0.5

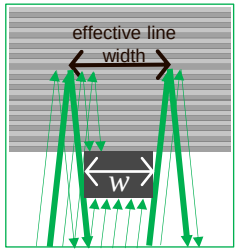
Agenda

- Summary of the Optics (Zeiss - Migura)
- Previous Quarter Field Concept
- New Half Field Concept
- Imaging verification
- Design challenges

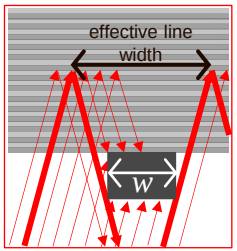
Summary of the previous presentation

11:00 AM – 11:25 AM EUV Lithography Optics for sub 9 nm Resolution
Sascha Migura, Carl Zeiss (Invited)

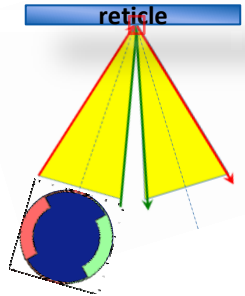
- 3D effects on the mask require the magnification to increase to 8x
- Two options are possible:
  - 8x isomorphic → 13mm slit
  - 4x/8x anamorphic → 26mm slit
- Potential to increase transmission ~2x
  - W.r.t. NXE:3300
  - By narrowing the angles in the optical system

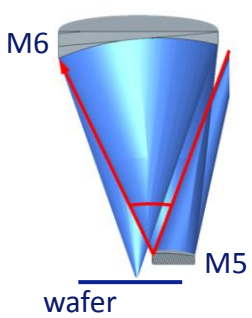


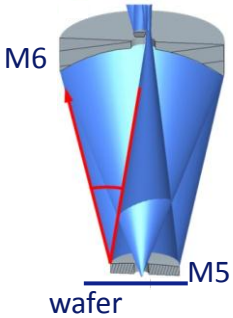
Small angle



Large angle



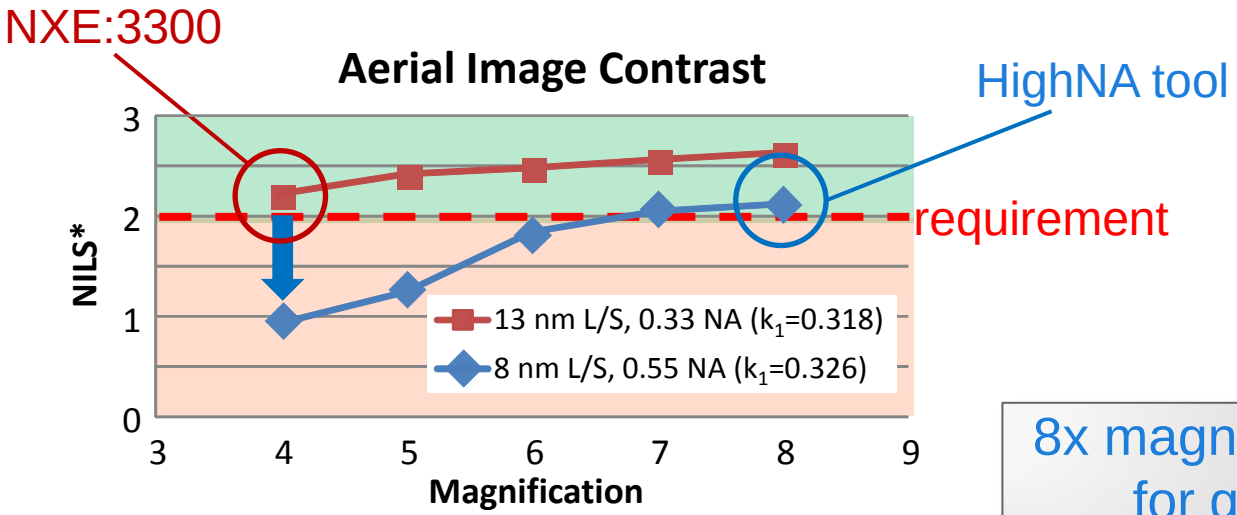




Previous Quarter Field concept

Image contrast increases with a larger magnification

Smaller angles restore the imaging quality



8x magnification required for good imaging

*NILS = Normalized Image Log Slope, measure for image contrast

HighNA Lens Scenarios

Conventional 4x lens versus Quarter Field 8x lens

4x Conventional
Full Field (FF)

104 mm

132 mm

y

Mask field size

4x

26 mm

33 mm

FF

Wafer field size

Imaging NOK

208 mm

264 mm

8x Lens
Full field (FF)

8x

FF

Larger Mask NOK

8x Lens
Quarter field (QF)

104 mm

132 mm

8x

13 mm

16.5 mm

QF QF
QF QF

HighNA Quarter Field concept impacts throughput

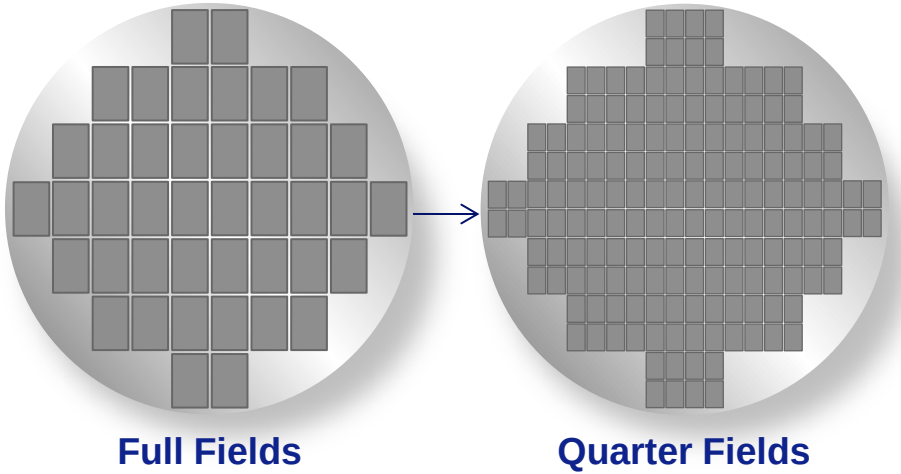
Faster stages required to compensate overhead

Speed of reticle will increase 4x:

- Magnification 2x (4x → 8x)
- Speed of wafer 2x (slit 26mm → 13mm)

Overhead time increases 16x:

- 4x more dies
- 4x longer acceleration time needed

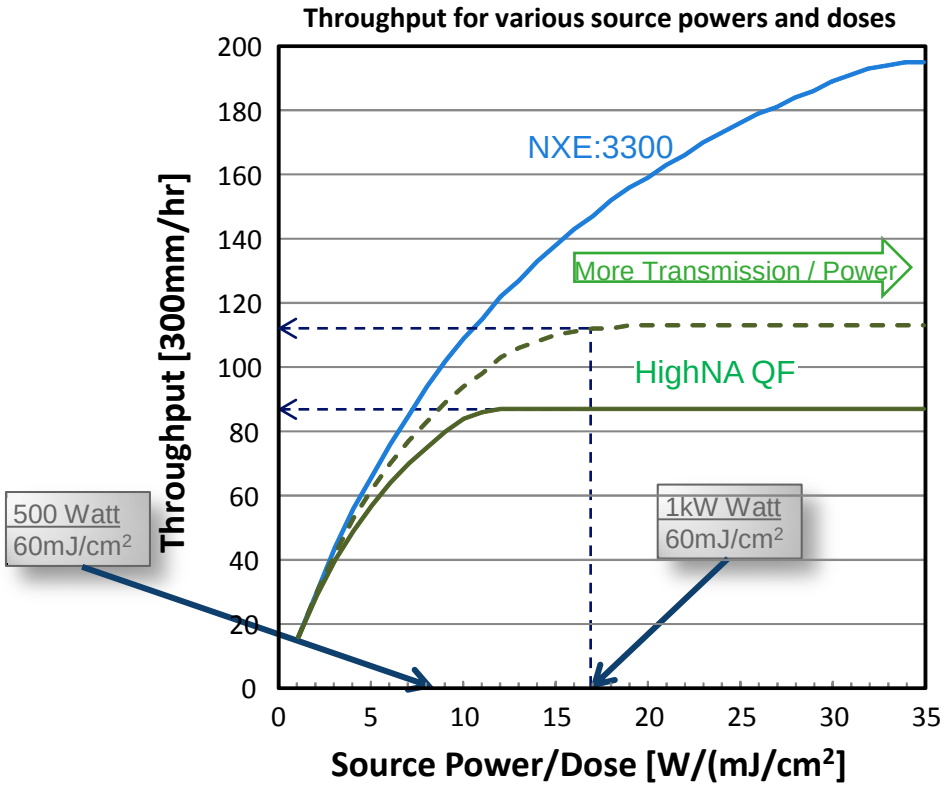


Full Fields **Quarter Fields**

Acceleration of the reticle stage needs to go up >>4x

HighNA Quarter Field productivity

QF limits TPT to 110wph, even with improved stage accelerations



WS,RS current performance

WS 2x, RS 4x

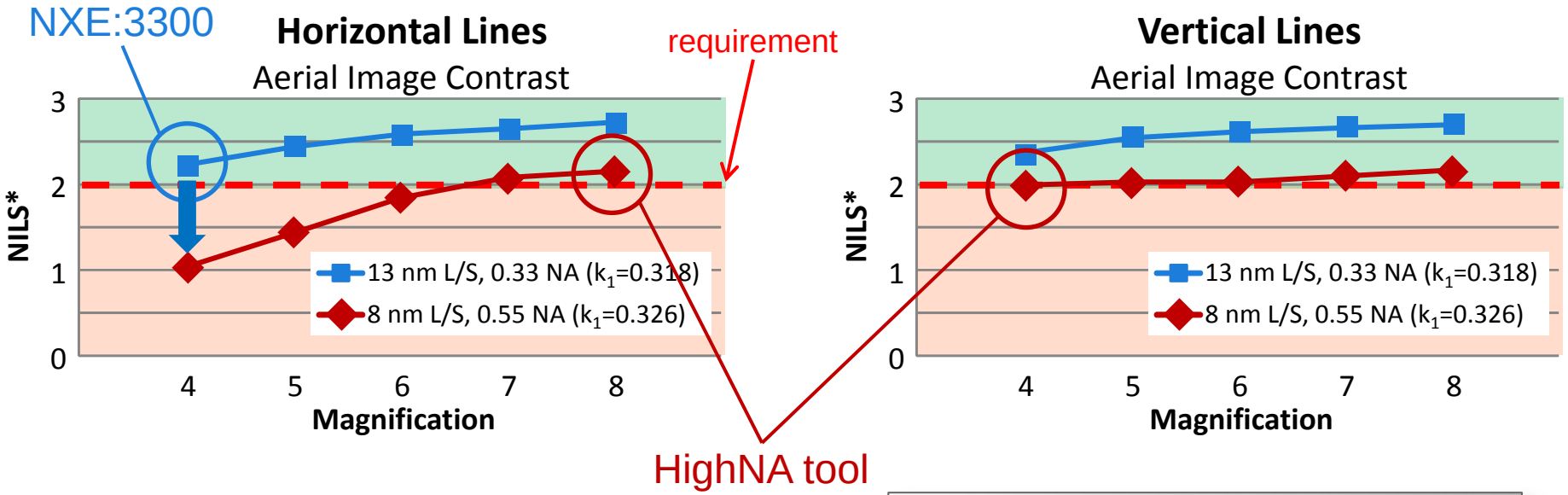
WS current, RS 2x

With double accelerations throughput still too low

New Half Field concept

Image contrast increases with a larger magnification

But: only needed for Horizontal Lines

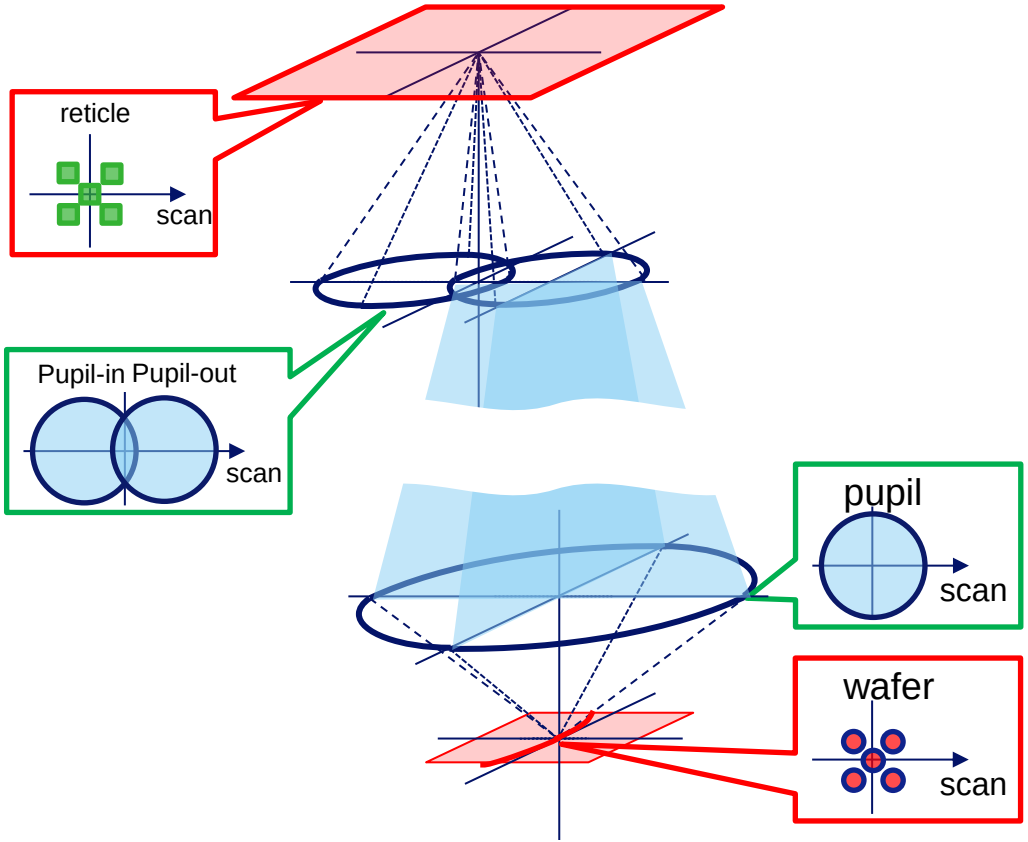


4x/8x anamorphic magnification required for HighNA imaging

*NILS = Normalized Image Log Slope

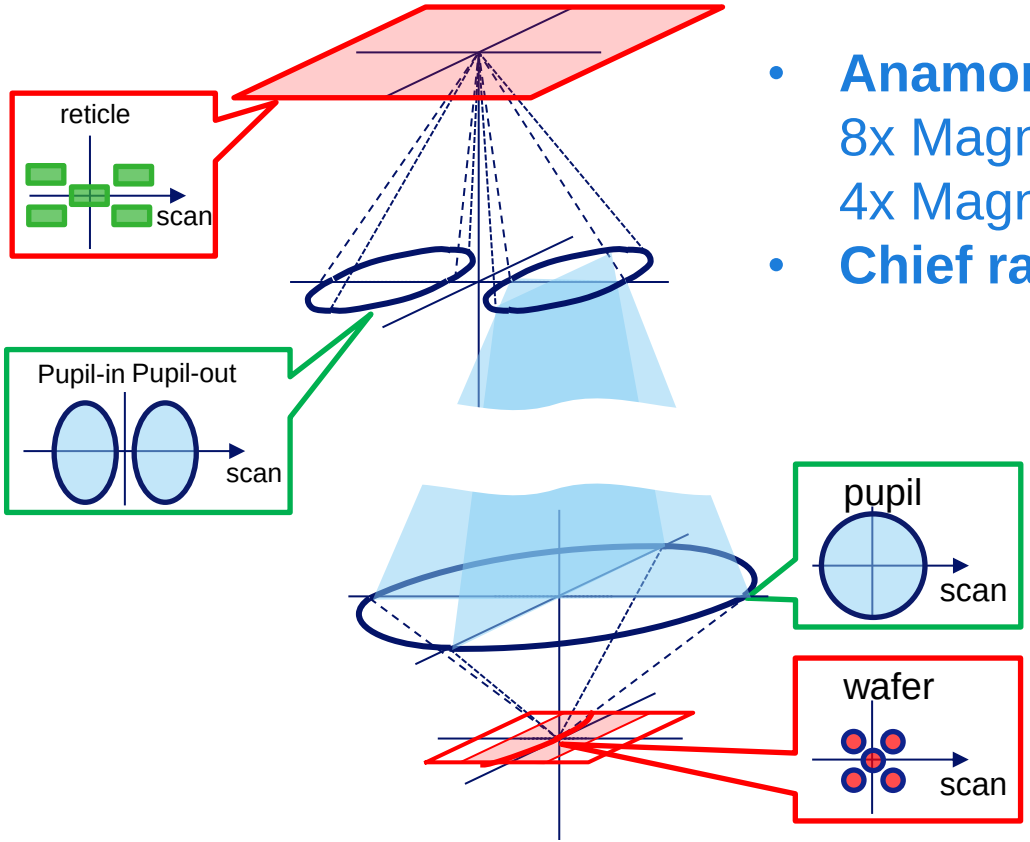
HighNA >0.5NA 4x magnification

Maintaining Chief Ray angle at Mask not possible



HighNA >0.5NA 4x/8x anamorphic magnification

Chief Ray Angle at Mask can be maintained

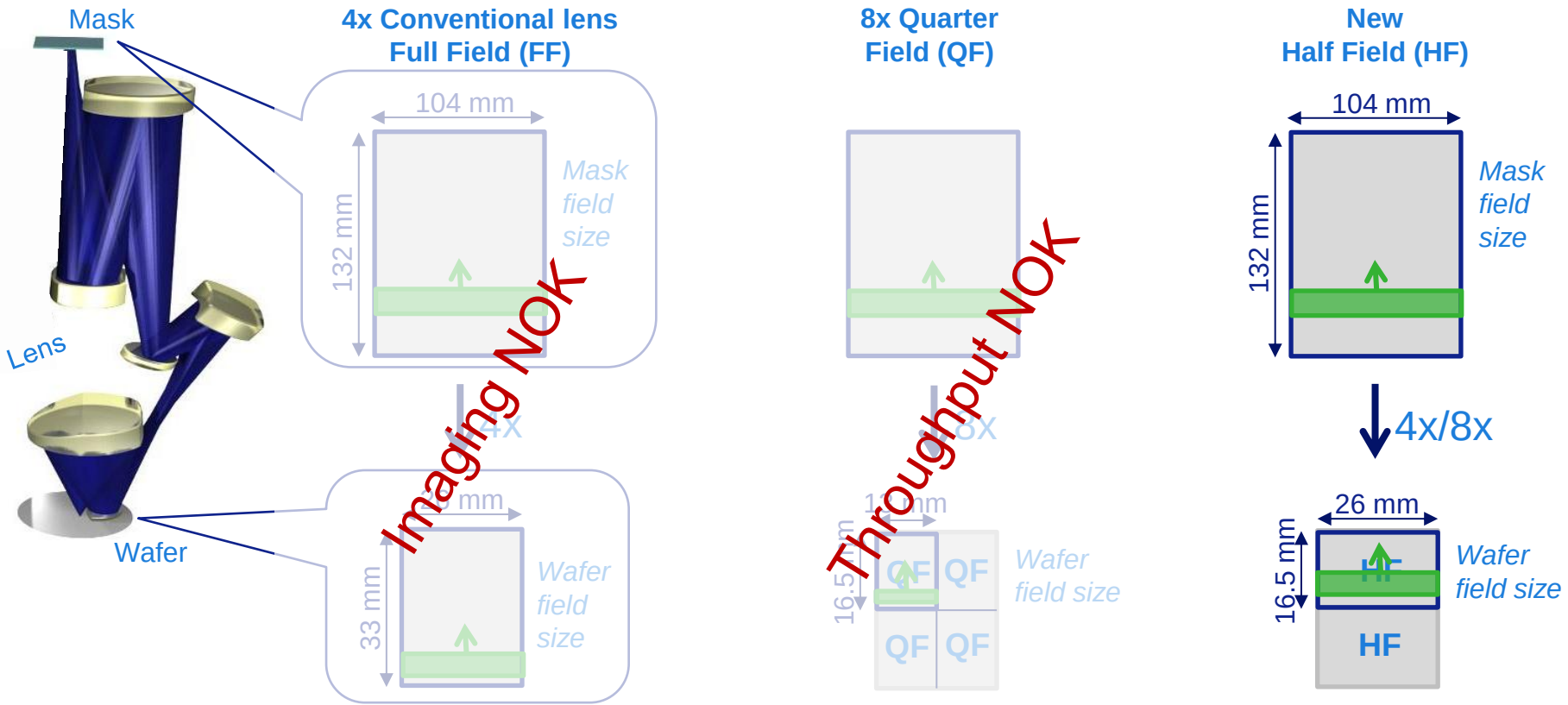


- **Anamorphic optics → half field:**
  8x Magnification in scan
  4x Magnification in other direction
- **Chief ray angle ok → Imaging ok**

The image at the mask needs to change

HighNA Lens Scenarios

Conventional 8x lens (QF) versus anamorphic Half-Field lens



Note: rectangular slit shown for illustration purposes

HighNA new Half Field concept

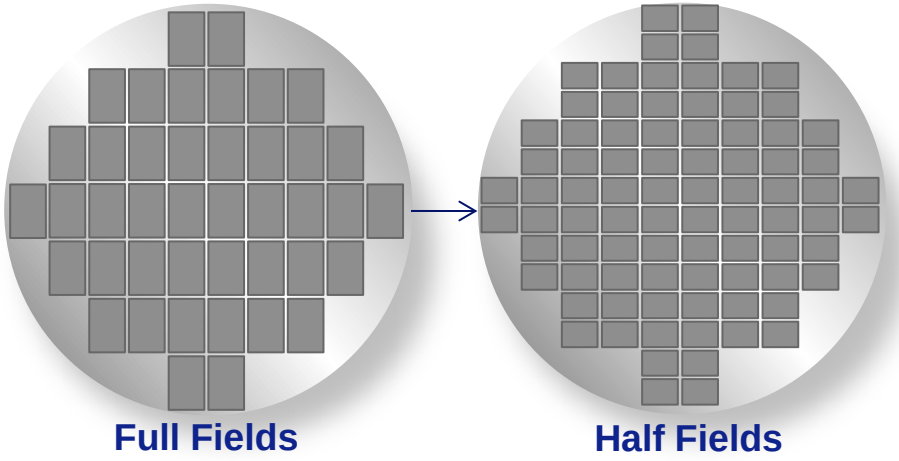
Less stringent demands on stages

Speed of mask will increase by 2x:

- Speed of wafer stays the same (26mm slit)
- Magnification 2x (4x → 8x)

Overhead increases 4x:

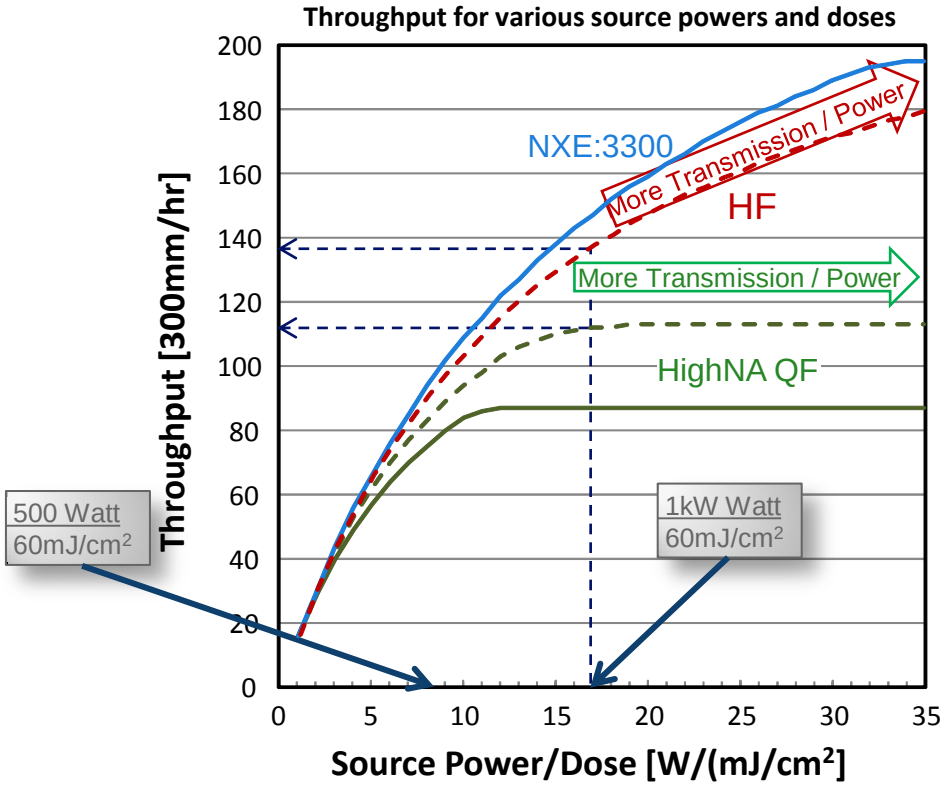
- 2x more dies
- 2x acceleration time needed



Acceleration of the reticle stage needs to go up ~4x

HighNA Field and Mask Size productivity

HF significantly improves throughput



WS, RS current performance

WS 2x, RS 4x

WS 2x, RS 4x

WS current, RS 2x

And there is even >180wph throughput potential!

3 options to utilize the 180wph throughput potential

Preferably by increasing the transmission of the optics

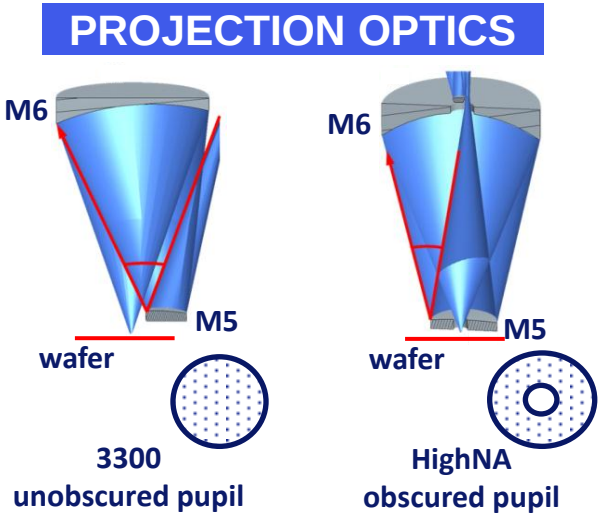
- Increase source power to ~2kW
  - We need to generate this 2kW
  - Additional heat loads need to be mitigated in the scanner

Not nice

- Reduce dose to ~30mJ/cm2
  - Smaller resolutions require larger doses to keep up with the LWR

Nice but feasible?

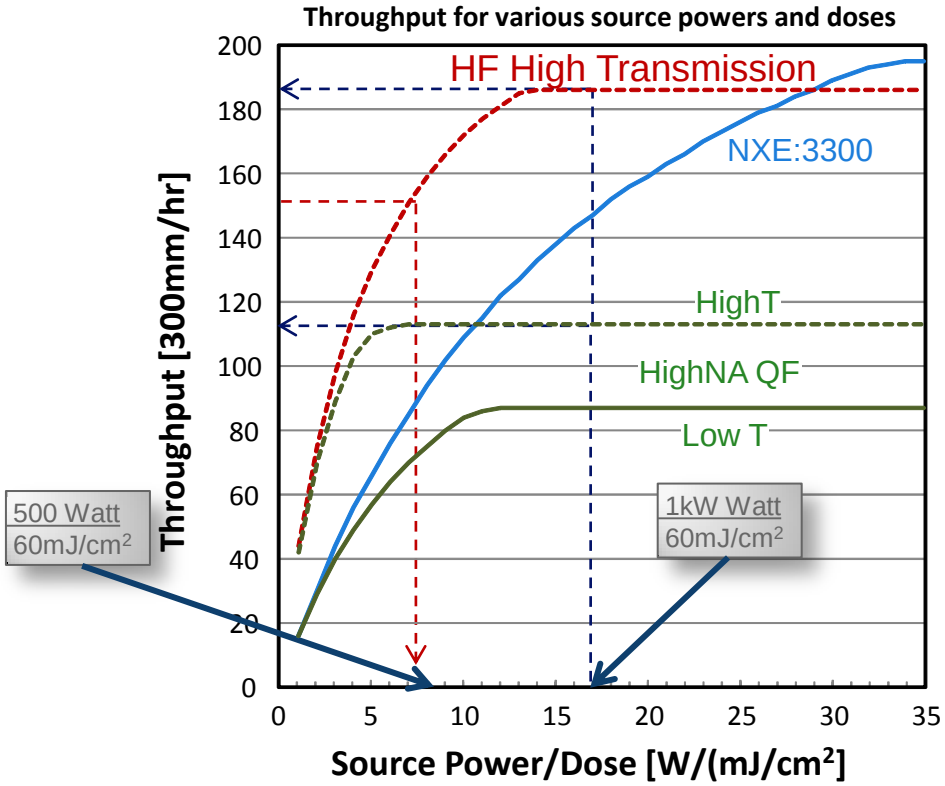
- Increase transmission ~2x
  - By narrowing the angles in the optics
  - Always preferred



Central obscuration reduces angles on M5

HighNA Field and Mask Size productivity

500W and ~2x transmission enables a TPT >150wph



WS, RS current performance
WS 2x, RS 4x

WS 2x, RS 4x

WS current, RS 2x

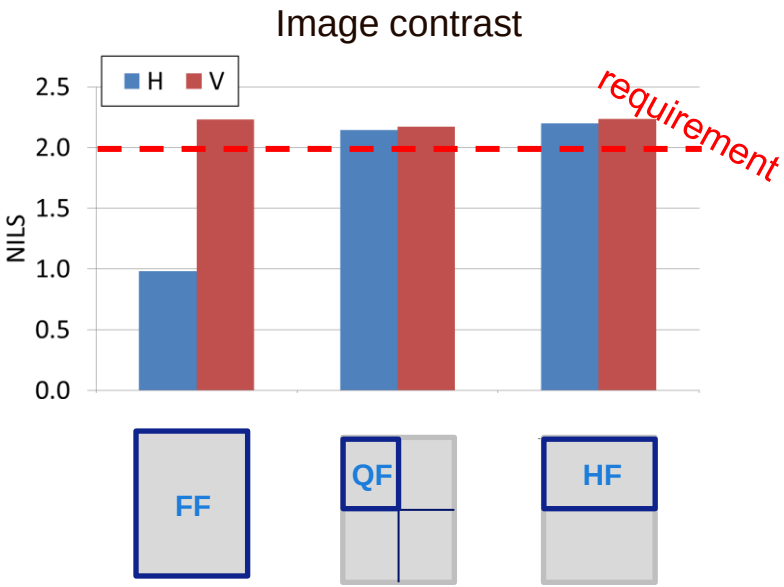
HighNA Half Field scanner with increased transmission needs 500W for 150wph at 60mJ/cm^2

Imaging Verification

Imaging verification of the new Half Field concept

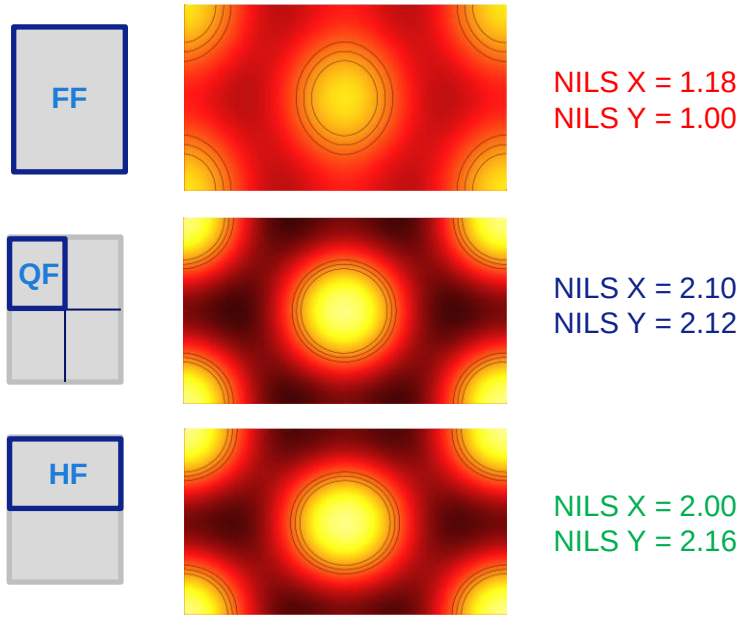
LS and CH's: no significant impact w.r.t. QF observed

8nm Dense Lines, NA=0.52



H: Horizontal lines
V: Vertical lines

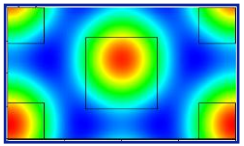
10.5nm Dense Contact Holes, NA=0.52



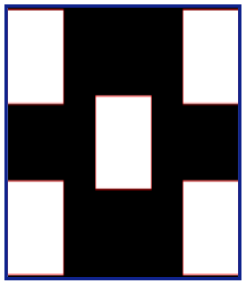
Verification of anamorphic modelling

Different simulation engines show consistent results.

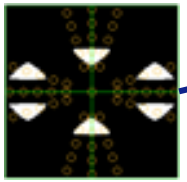
- NILS for 10.5 nm staggered CH's, 0.52NA
  - Zeiss model
  - HyperLith simulations

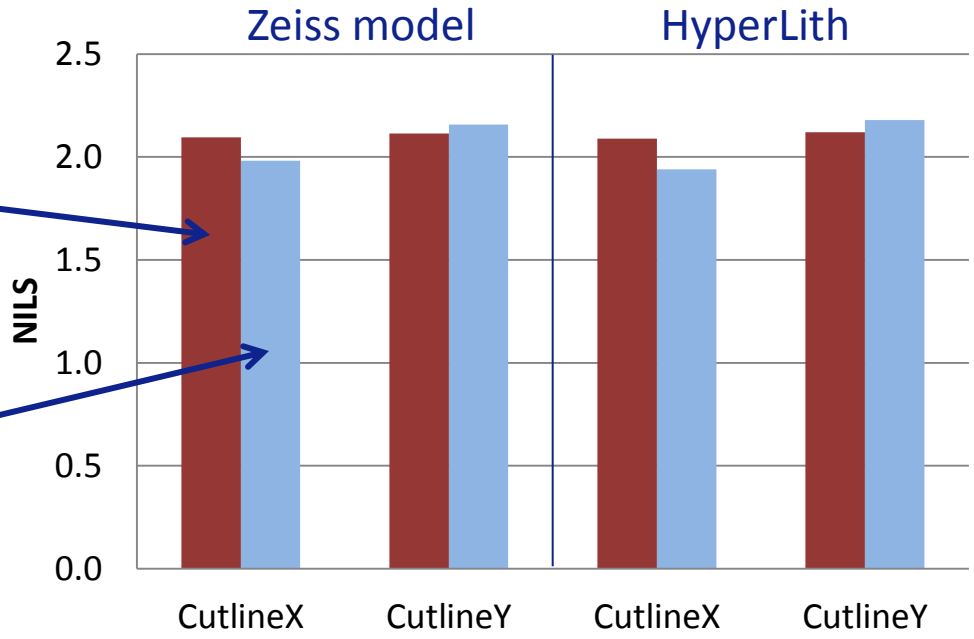


8x mask and circular pupil



4x/8x mask and elliptical pupil





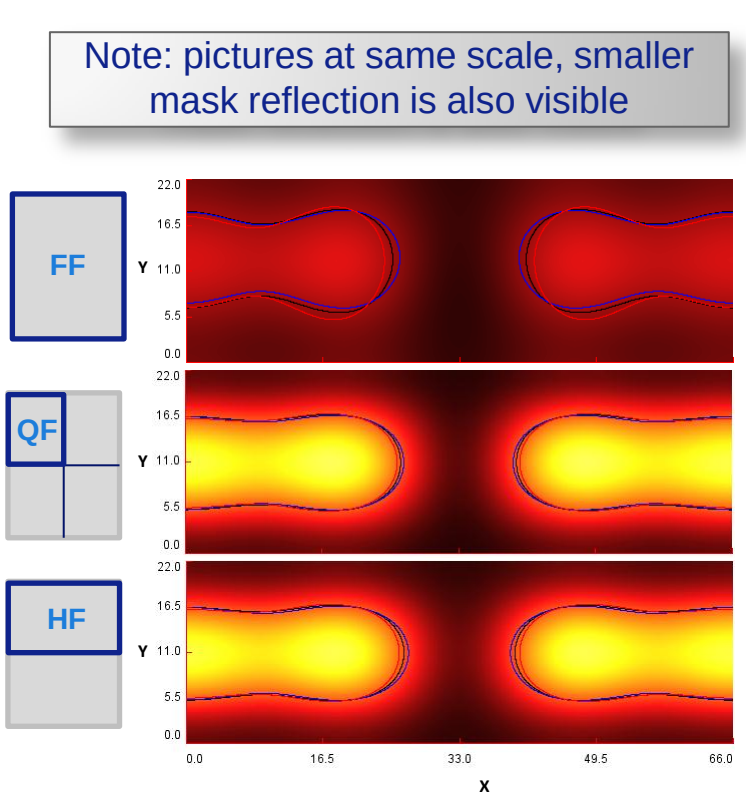
Jens Timo Neumann, Matthias Rösch, Lit-SKA, Laurens de Winter, ASML

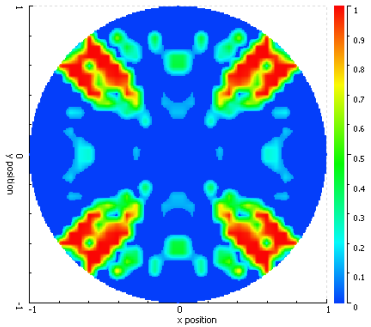
Imaging verification of the new Half Field concept

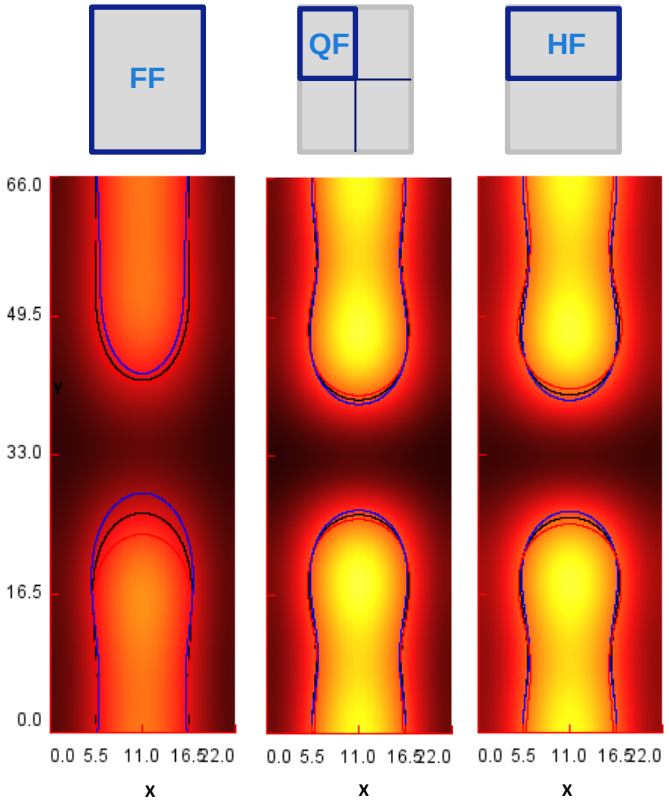
Logic N5 Line Ends 11nm HP L/S, 16.5nm gap size, NA=0.52

Aerial Image Intensity in HyperLith

Note: pictures at same scale, smaller mask reflection is also visible





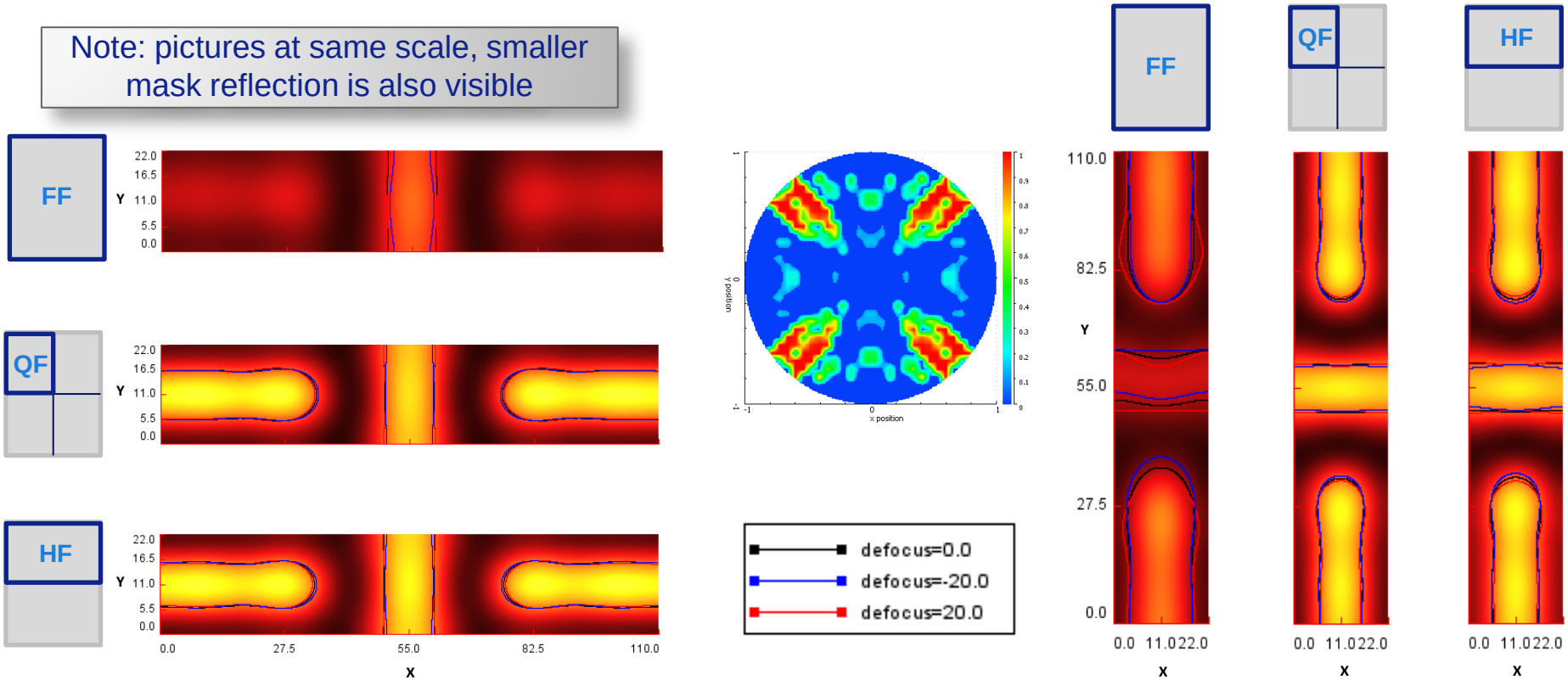


Imaging verification of the new Half Field concept

Logic N5 Open T, 11nm HP L/S, 16.5nm gap size, NA=0.52

Aerial Image Intensity in HyperLith

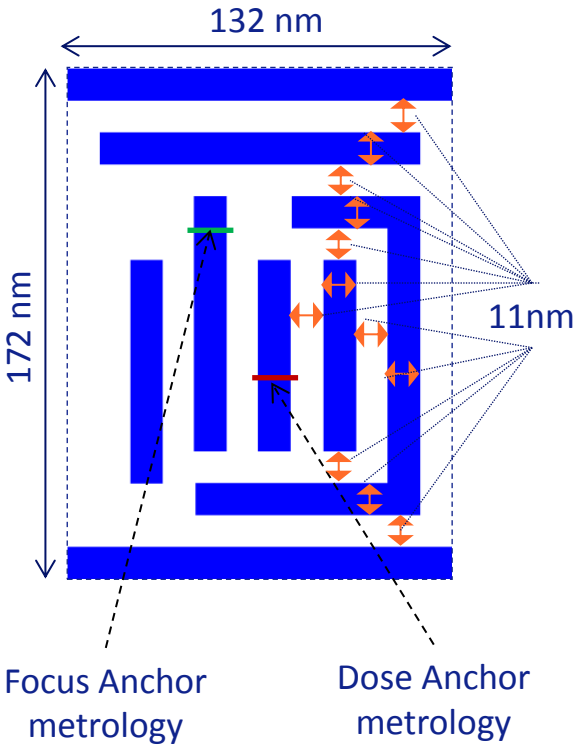
Note: pictures at same scale, smaller mask reflection is also visible



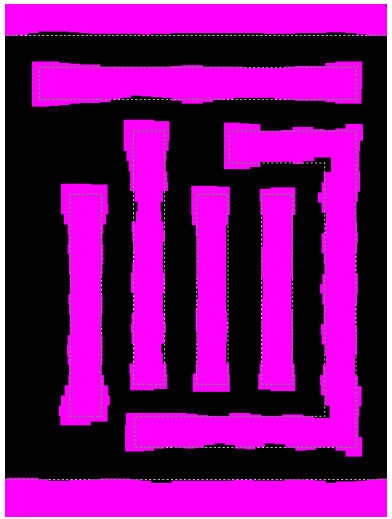
Imaging verification of the new Half Field concept

Logic N5 clip Metal-1, 11nm lines. OPC

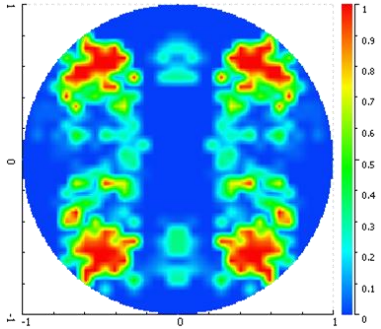
Target Pattern



Mask Pattern 8x



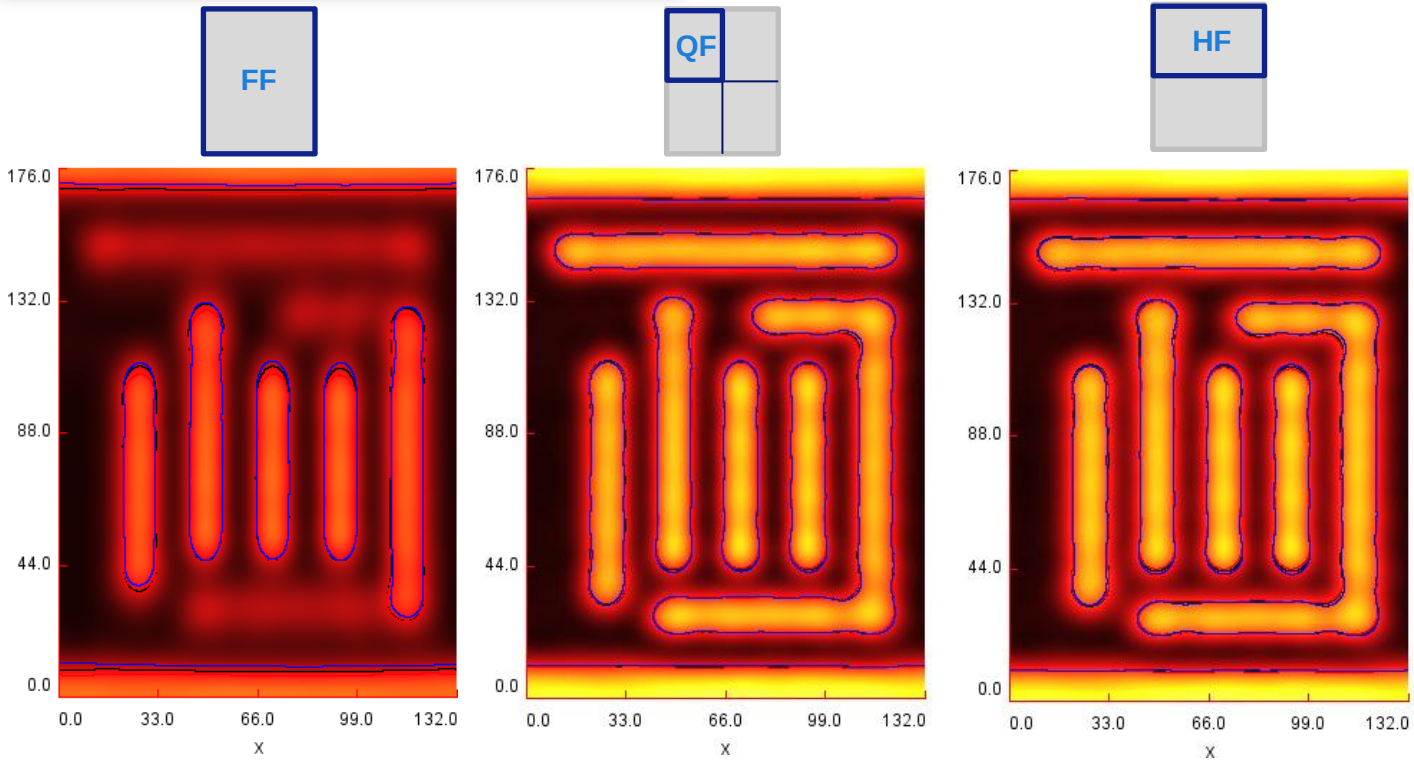
Illumination Pattern 8x



Imaging verification of the new Half Field concept

Logic N5 clip Metal-1, 11nm lines Aerial Image Intensity in Hyperlith

Note: pictures at same scale, smaller mask reflection is also visible

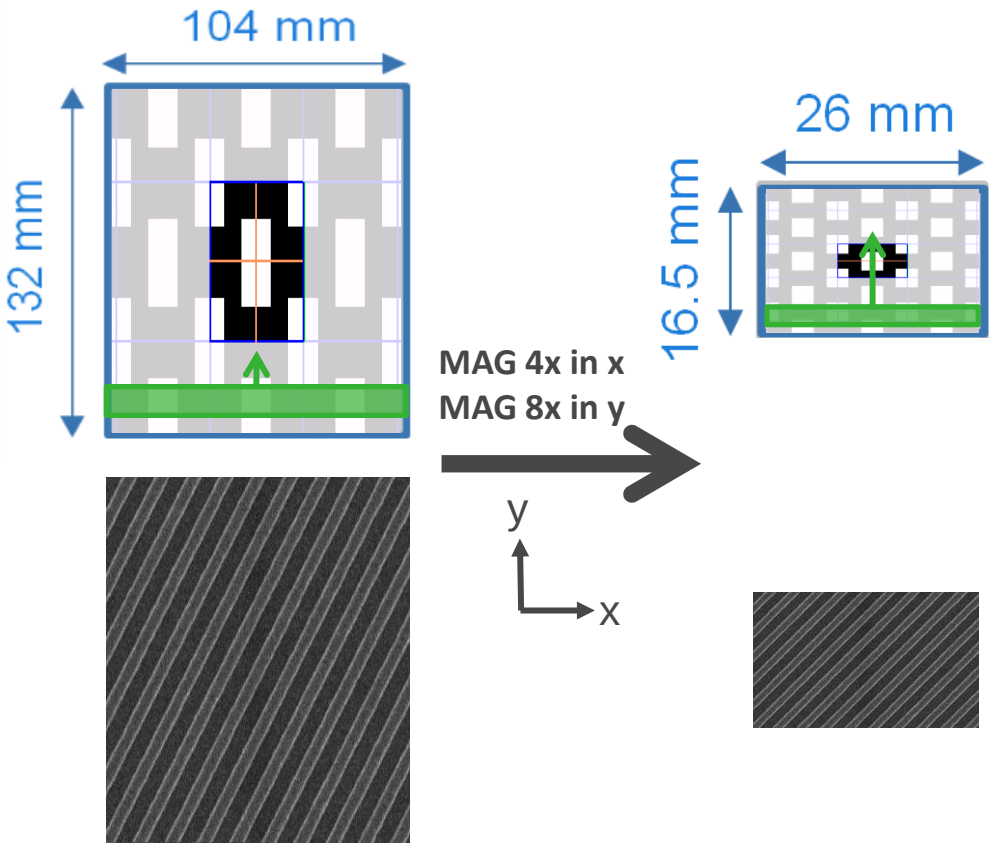


Design Challenges

Some Mask Consequences

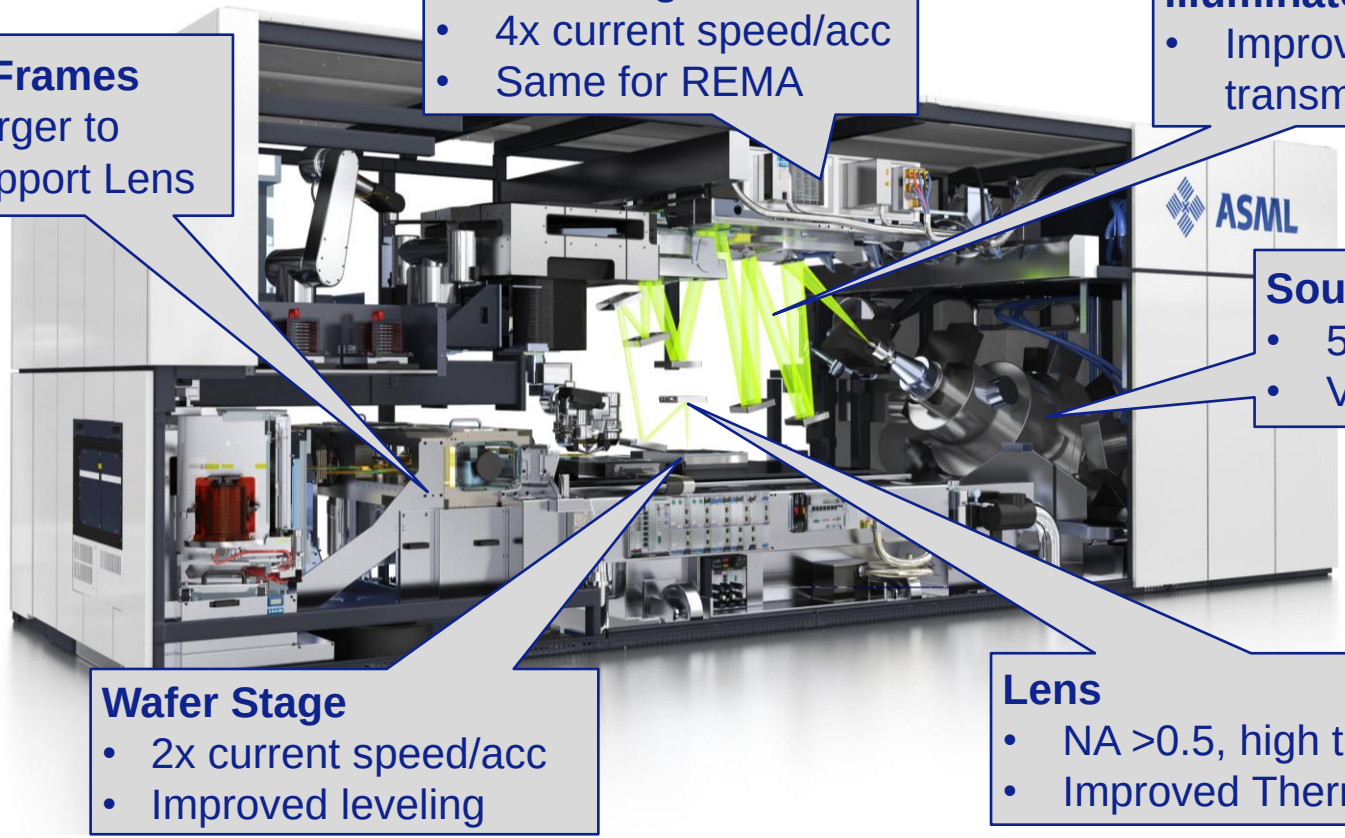
The anamorphic lens must be able to project a stretched mask pattern

- The image on the mask is a stretched version of the image on the wafer
  - A 1:2 rectangle on the mask will yield a square pattern on the wafer
- Angles do not stay the same
  - An intended 45deg line will have a different angle on the reticle



Note: rectangular slit shown for illustration purposes

Overview main System Changes HighNA tool



Reticle Stage
- 4x current speed/acc
- Same for REMA

Illuminator
- Improved transmission

New Frames
- Larger to support Lens

Source
- 500W/1kW
- Vertical position

Wafer Stage
- 2x current speed/acc
- Improved leveling

Lens
- NA >0.5, high transmission
- Improved Thermal Control

High-NA EUV impact of HF on RS architecture

New SS, LoS actuators, motor cooling, reticle clamp & thermal control needed

Stage mass & volume increase (by added motor mass)
- Reluctance SS actuators
- LoS moving magnet actuators

Peak electrical power
- Pursue lower stage mass
- New LoS power amplifiers

Dissipated power
- Pursue lower stage mass
- Alternative motor cooling

Reticle heat load
- Reticle thermal control solutions needed

Reticle clamping pressure
- Novel clamp to overcome reticle slip

Summary

The Half Field anamorphic concept is a breakthrough for HighNA EUVL:

- Full Field with 6” masks can not be extended towards HighNA
- Original Quarter Field concept limited to ~100wph
- New Half Field concept has potential of >180wph

We can now extend the EUV Roadmap to >0.5NA

- With using 6” mask
- Good throughput potential
- 26 x 16.5 mm^2 image field (Half Field)

Acknowledgements

Panoramic:

- Tom Pistor

Zeiss HighNA team in Oberkochen

ASML HighNA team in Veldhoven

ASML Top module team in Wilton

Lack of money is no obstacle,
lack of an idea is an obstacle

Ken Hakuta